1 TITLE OF THE INVENTION

2 VEHICLE SURROUNDINGS MONITORING APPARATUS

3

4 BACKGROUND OF THE INVENTION

5 1.   Field of the invention

6   The present invention relates to a vehicle surroundings

7 monitoring apparatus and more in particular to a vehicle

8 surroundings monitoring apparatus suitable for detecting solid

9 objects successively disposed along roads such as guardrails,

10 side walls and the like.

11 2.   Prior arts

12   With increased number of vehicles and with increased

13 number of traffic accidents, the conception of Advanced Safety

14 Vehicle (ASV) is becoming one of primary strategies in designing

15 a vehicle.   In   particular,   an   ASV   technology   raises   the

16 intelligence level of a vehicle through the state of the art

17 electronic technologies. In recent years, various safety devices

18 such as issuing an alarm to inform a vehicle driver of a likelihood

19 of collision, stopping a vehicle, decreasing or increasing the

20 speed of the vehicle by detecting a vehicle traveling ahead or

21 an obstacle through a television camera, a laser-beam radar or

22 the like, have been proposed.

23   The applicant of the present invention, in Japanese

24 Patent Application Laid-open No. Toku-Kai-Hei 5-265547, have

25 already disclosed a technique in which images taken by two

26 stereoscopic cameras are transformed into distance images, these

27 distance images being divided into lattice-like small regions

28 at a prescribed interval to detect solid objects for each small

1

1 region. Further, the applicant, in Japanese Patent Application

2 Laid-open No. Toku-Kai-Hei 6-266828, have already proposed a

3 technique wherein similarly data of solid objects per small

4 region are extracted, these data being processed by a so called

5 "Hough" transformation method to detect the solid objects such

6 as side walls and guardrails aligned along roads.

7 However, according to these known arts, since the data

8 of solid objects are processed by the "Hough" transformation

9 method and the like, as a result, with respect to the solid objects

10 provided along a curved road like guardrails, only their small

11 portions located within a relatively short distance are

12 recognized as straight lines, therefore it is much more difficult

13 to recognize those objects in the distance.

14

15 SUMMARY OF THE INVENTION

16 The present invention is intended to obviate the

17 aforesaid problem of the prior arts and it is an object of the

18 present invention to provide a vehicle surroundings detecting

19 apparatus capable of detecting a series of solid objects which

20 constitute a boundary of a road as a wall surface even in case

21 where the road is curved.

22 In order to achieve the object, the present invention

23 comprises a wall surface detecting means for dividing positional

24 data of solid objects into groups and based on the grouped

25 positional data of the solid objects for detecting a wall surface

26 formed along a boundary of a road, a wall surface model forming

27 means for interconnecting a plurality of nodes and based on the

28 interconnected nodes for forming a wall surface model to express

1 an outline of the side wall and a wall surface model correcting

2 means based on the grouped positional data of the solid objects

3 for correcting the wall surface model.

4

5 BRIEF DESCRIPTION OF THE DRAWINGS

6   Fig. 1 is an overall view of a vehicle surroundings

7 detecting apparatus mounted on a vehicle;

8   Fig. 2 is a schematic block diagram of a vehicle

9 surroundings detecting apparatus according to the present

10 invention;

11   Fig. 3 is a first flowchart showing a flow of control

12 of a solid object/side wall group detecting process;

13   Fig. 4 is a second flowchart showing a flow of control

14 of a solid object/side wall group detecting process;

15   Fig. 5 is a third flowchart showing a flow of control

16 of a solid object/side wall group detecting process;

17   Fig. 6 is a flowchart showing a flow of control of a

18 wall surface detecting process;

19   Fig. 7 is a first flowchart showing a flow of control

20 of a wall surface position correcting process;

21   Fig. 8 is a second flowchart showing a flow of control

22 of a wall surface position correcting process;

23   Fig. 9 is an explanatory view showing an example of

24 images taken by cameras mounted on a vehicle;

25   Fig. 10 is an explanatory view showing an example of

26 distance images shown in Fig. 9;

27   Fig. 11 is an explanatory view showing the position

28 of solid objects detected per respective strips;

1   Fig. 12 is an explanatory view showing the result of

2 detection of side walls;

3   Fig. 13 is an explanatory view showing the result of

4 detection of side walls in terms of the X-Z plane;

5   Fig. 14 is a schematic view showing a wall surface

6 model;

7   Fig. 15 is an explanatory view showing the way of

8 searching a wall surface pattern;

9   Fig. 16 is an explanatory view showing an example of

10 a pattern of a weight coefficient;

11   Fig. 17 is an explanatory view showing the result of

12 calculation of a degree of coincidence;

13   Fig. 18 is an explanatory view showing the connection

14 of nodes;

15   Fig. 19 is an explanatory view showing the result of

16 detection of wall surfaces; and

17   Fig. 20 is an explanatory view showing the result of

18 detection of wall surfaces in terms of the X-Z plane.

19

20 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

21   Referring now to Fig. 1, reference numeral 1 denotes

22 a vehicle on which a vehicle surroundings monitoring apparatus

23 2 is mounted for imaging objects within a visible scope ahead

24 of the vehicle and for recognizing the objects for monitoring.

25 The vehicle surroundings monitoring apparatus 2 comprises a

26 stereoscopic optical system 10 for imaging objects from two

27 different positions, an image processor 20 for processing images

28 of these objects to obtain three-dimensional distance

1 distribution information, and a recognition/judgment computer

2 30 for detecting three-dimensional positions of roads and solid

3 objects at high speeds based on the distance information inputted

4 from the image processor 20, for identifying a preceding vehicle

5 or an obstacle based on the result of the detection and for judging

6 whether or not an alarm should be issued to avoid a collision

7 with the preceding vehicle or the obstacle.

8   The recognition/judgment computer 30 is connected with

9 sensors such as a vehicle speed sensor 4, a steering angle sensor

10 5 and the like in order to detect a present traveling condition

11 of the vehicle and also it is connected with a display 9 provided

12 at the front of a vehicle driver for informing hazard. Further,

13 the computer 30 is connected with an external interface for

14 example for controlling actuators (not shown) which operate so

15 as automatically to avoid a collision with the obstacle or the

16 vehicle traveling ahead.

17   The stereoscopic optical system 10 is composed of a

18 pair of left and right CCD (Charge Coupled Device) cameras 10a,

19 10b. A pair of stereoscopic images taken by the CCD cameras 10a,

20 10b are processed in the image processor 20 according to the

21 principle of triangulation to obtain three-dimensional distance

22 distribution over an entire image.

23   The recognition/judgment computer 30 reads the

24 distance distribution information from the image processor 20

25 to detect three-dimensional positions with respect to the

26 configuration of roads and solid objects such as vehicles and

27 obstacles at high speeds and judges a possibility of collision

28 or contact with these detected objects based on the traveling

5

1 condition detected by the vehicle speed sensor 4 and the steering

2 angle sensor 5 of the self vehicle to inform the vehicle driver

3 of the result of the judgment through the display 9.

4 Fig. 2 shows a constitution of the image processor 20

5 and the recognition/judgment computer 30. The image processor

6 20 comprises a distance detecting circuit 20a for producing

7 distance distribution information and a distance image memory

8 20b for memorizing this distance distribution information. More

9 specifically, the distance detecting circuit 20a calculates a

10 distance to a given object by selecting a small region imaging

11 an identical portion of the object from the left and right

12 stereoscopic images taken by the CCD cameras 10a, 10b,

13 respectively and then obtaining a deviation between these two

14 small regions and outputs in the form of three-dimensional

15 distance distribution information.

16 Fig. 9 shows an example of either of images taken by

17 the left and right CCD cameras 10a, 10b. When this image is

18 processed by the distance detecting circuit 20a, the distance

19 distribution information outputted from the distance detecting

20 circuit 20a is expressed as a distance image as shown in Fig.

21 10.

22 The example of the distance image shown in Fig. 10 has

23 a picture size composed of 600 (laterally) x 200 (longitudinally)

24 picture elements. The distance data are included in white dotted

25 portions that correspond to the portions having a large difference

26 of brightness between two adjacent picture elements aligned in

27 the left and right direction respectively in the image shown in

28 Fig. 9. Further, in this example, the distance detecting circuit

6

1 20a treats ● distance image as an image composed of 150

2 (laterally) x 50 (longitudinally) blocks, i.e., 4 x 4 picture

3 elements for one block or one small region. The calculation of

4 distance is performed for each block of the left and right images.

5 The recognition/judgment computer 30 comprises a

6 microprocessor 30a primarily for detecting the road configuration,

7 a microprocessor 30b primarily for detecting solid objects based

8 on the configuration of a road detected and a microprocessor 30c

9 primarily for identifying a preceding vehicle or an obstacle based

10 on the positional information of the detected solid objects and

11 for judging a possibility of collision or contact with the

12 preceding vehicle or the obstacle and these microprocessors 30a,

13 30b, 30c are connected in parallel with each other through a system

14 bus 31.

15 The system bus 31 is connected with an interface circuit

16 32 to which the distance image is inputted from the distance image

17 memory 20b, a ROM 33 for storing a control program, a RAM 34 for

18 memorizing miscellaneous parameters produced during

19 calculations, an output memory 35 for memorizing the result of

20 processing, a display controller 30d for controlling the display

21 9 and an I/O interface circuit 37 to which signals are inputted

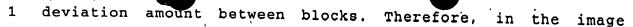22 from the vehicle speed sensor 4 and the steering angle sensor

23 5.

24 As shown in Fig. 9, the distance image has a coordinate

25 system composed of a lateral axis i, a longitudinal axis j and

26 a vertical axis dp with an origin of the coordinates placed at

27 the left below corner of the distance image. The vertical axis

28 dp indicates a distance to an object which corresponds to the

1 deviation amount between blocks. Therefore, in the image

2 processing computer 30, a point (i, j, dp) on the distance image

3 is transformed into a coordinate system provided in the real space

4 to perform processes such as recognition of the road configuration,

5 detection of the position of solid objects and the like.

6   That is to say, with respect to the three-dimensional

7 coordinate system fixed to a self vehicle in the real space,

8 setting X axis on the right side with respect to the traveling

9 direction of the self vehicle (vehicle 1), Y axis in the upward

10 direction of the vehicle 1 and Z axis in the forward direction

11 of the vehicle and placing an origin of the coordinates on the

12 road surface underneath the center of two CCD cameras 10a, 10b,

13 X-Z plane (Y = 0) coincides with the road surface, if the road

14 is flat. Accordingly, the point (i, j, dp) on the distance image

15 can be transformed into a point (x, y, z) in the real space as

16 follows:

17 $$x = CD / 2 + z \cdot PW \cdot (i - IV) \qquad \ldots \ldots (1)$$

18 $$y = CH + z \cdot PW \cdot (j - JV) \qquad \ldots \ldots (2)$$

19 $$z = KS / dp \qquad \ldots \ldots (3)$$

20 where CD is an interval between CCD cameras 10a, 10b; PW is an

21 angle of visibility per picture element; CH is a height of CCD

22 cameras when measured from the road surface; IV, JV are

23 coordinates of an infinite point directly in front of the vehicle

24 1 on the image; and KS is a distance coefficient (KS = CD / PW).

25   Rewriting the above equations (1), (2) and (3) as

26 follows:

27 $$i = (x - CD / 2) / (z \cdot PW) + IV \qquad \ldots \ldots (4)$$

28 $$j = (y - CH) / (z \cdot PW) + JV \qquad \ldots \ldots (5)$$

8

1          $dp = KS / z$ .... (6)

2   Next, processes in the recognition/judgment computer

3 30 will be described.

4   In the microprocessor 30a, first, actual lane markers

5 of a road are extracted from three-dimensional positional

6 information contained in the distance image which is stored in

7 the distance image memory 20b and then the configuration of the

8 road is recognized by modifying parameters of a built-in road

9 model so as to agree with the actual road configuration.

10   The road model described above is expressed by a

11 plurality of three-dimensional linear equations. That is, the

12 imaged left and right lane markers of the road on which the subject

13 vehicle is traveling are divided into a plurality of intervals

14 determined according to distance and the road model is formed

15 by a plurality of broken lines each of which is expressed for

16 every interval in the following three-dimensional linear

17 equations:

18         $x = a \cdot z + b$ .... (7)

19         $y = c \cdot z + d$ .... (8)

20 where a, b are parameters of a linear equation extended in the

21 horizontal direction in the coordinate system of the real space

22 and c, d are parameters of a linear equation extended in the

23 vertical direction in the coordinate system of the real space.

24   In the microprocessor 30b wherein the detection of

25 solid objects is processed, the distance image is divided into

26 lattice-like strips having a prescribed interval and data of

27 solid objects are extracted for every strip. Then, a histogram

28 is produced per each of these strips based on the data of solid

9

1   objects and the position on the X-Y plane of solid objects

2   representing respective strips and the distance thereto are

3   obtained from the histogram. Then, comparing the image

4   successively from the left to the right, the images having close

5   distances in the forward and backward direction (Z-axis

6   direction) and the lateral direction (X-axis direction) are

7   classified into the same group. Further, when the arrangement

8   direction of the data is checked, the portion where the

9   arrangement direction is largely changed is found, the group

10 being divided in a different group.

11 ~~Further, based on the arrangement direction of the~~

12 distance data of the overall groups, i.e., the gradient with

13 respect to the Z-axis, the groups are classified into solid object

14 groups or side wall groups. For the solid object groups,

15 parameters such as a mean distance, X coordinates of the left

16 and right ends and the like are calculated from the distance data

17 of the group. Further, for the side wall groups, parameters such

18 as the arrangement direction (gradient with respect to the Z-axis),

19 the positions of the forward and backward ends in terms of Z-X

20 coordinates and the like are calculated. Thus, the front end,

21 the side surface and the rear end of a solid object and the

22 structure such as a guardrail are detected as the side wall

23 ~~arranged along the road.~~

24 With respect to the generation of distance image, the

25 process of detecting the configuration of roads from the distance

26 image and the process of the judgment of collision or contact

27 with obstacles, details of which are described in Japanese Patent

28 Application Laid-open No. Toku-Kai-Hei 5-265547 and No.

10

1 Toku-Kai-Hei 6-266828 both of which have been proposed by the

2 applicant of the present invention.

3 The present invention is characterized in that even

4 when the road is curved, the wall surface can be recognized up

5 to the far distance along the curved road. The process in the

6 microprocessor 30b will be described according to the flowcharts

7 shown in Fig. 3 through Fig. 8.

8 ~~The programs shown in Figs 3 through 5 are ones for~~

9 classifying the solid object group and the side wall group by

10 processing the distance data obtained from the distance image.

11 First, at a step S101, the distance image is divided into

12 lattice-like strips having a given interval (for example 8 to

13 20 picture elements) and at S102 data of a solid object are

14 extracted for every strip and the data of the first strip are

15 read to calculate the distance to the object.

16 Next, the program goes to S103 where the data of the

17 first strip are set and at S104 the three-dimensional position

18 (x, y, z) of the object is obtained according to the aforesaid

19 equations (1) to (3). Then, the program goes to S105 where the

20 height yr of the road surface at the distance z is calculated

21 according to the linear equations (7) and (8) expressing the road

22 configuration. In case where the road configuration can not be

23 recognized for example on a road having no lane marker, the road

24 surface being assumed to be in a horizontal relation with the

25 vehicle 1, the road height is established to be zero for example.

26 Next, the program goes to S106 where the data above

27 the road surface are extracted as the solid object data based

28 on the height H from the road surface which is calculated according

1 to the following equation (9).

2 $$H = y - yr \qquad \dots (9)$$

3 In this case, if the height H of the object is 0.1 meters or smaller,

4 since the object of this size is supposed to be a lane marker,

5 a stain or a shadow on the road, the data of the object are

6 discarded. Similarly, since the object which is located at a

7 position higher than the self vehicle 1 is supposed to be a bridge

8 or a signpost, that object is discarded. Thus, only the data of

9 objects which are estimated to be solid objects on the road are

10 selected.

11 After that, the program goes to S107 where it is checked

12 whether or not the data is final one of the strip. If the data

13 is not final, after the next data is set at S108, the program

14 returns to S104 and similar processes are repeated to extract

15 the data above the road surface. Further, when the final data

16 of the strip are finished to be processed, the program goes from

17 S107 to S109 wherein a histogram is prepared. The histogram is

18 composed of a number of data contained within a predetermined

19 interval of the distance z which is aligned on the lateral axis.

20 At the next step S110, if there is an interval in which

21 the frequency (number of data) is above a threshold value and

22 further indicates a maximum value, it is judged that a solid object

23 exists within that interval and the distance to the object is

24 detected. Thus prepared histogram also contains data erroneously

25 detected and therefore some data appear in the position where

26 no object exists. However, it should be noted that if there is

27 an object having some degrees of size in a position, the frequency

28 at the position shows a relatively large value and if there is

12

1 no object, the frequency is relatively small.

2 Accordingly, it is permissible to judge that if the
3 frequency of the histogram exceeds a predetermined threshold
4 value and besides shows a maximum value in an interval, an object
5 exists in the interval and that if the maximum value of the
6 frequency is below the threshold value, no object exists. Even
7 in case where some amount of noises are included in the image
8 data, it is possible to detect an object with minimum effect of
9 noises.

10 After that, the program goes from S111 to S112 where
11 it is checked whether or not the process has reached a final strip.
12 If it is judged that the process has not yet reached a final strip,
13 the program returns to S103 and similar processes are repeated.
14 When the process reaches the final strip, the program goes from
15 S112 to S114.

16 Fig. 11 is a view showing the position of solid objects
17 detected for each strip from the original image. The distance
18 data of these solid objects are classified into groups having
19 a close distance with each other by the processes executed at
20 the steps S114 to S120. The grouping will be performed as follows.
21 In these processes, the detected distances of the solid objects
22 in respective strips are investigated. If the difference of the
23 detected distances to the solid objects between adjacent strips
24 is smaller than a threshold value, these objects are deemed to
25 be the same objects and on the other hand, if that difference
26 exceeds the threshold value, those objects are regarded as
27 different objects.

28 Specifically, at S114, the first strip (for example,

13

1 a strip of the left end) is investigated and if a solid object

2 is detected therein, the distance data are read and this strip

3 R1 is classified into a group G1 having a distance Z1. Next, the

4 program goes to S115 where the right adjacent strip R2 is

5 investigated. If no solid object is detected in the strip R2,

6 it is judged that the group G1 exists within the strip R1 or in

7 the neighborhood thereof and the distance is Z1. On the other

8 hand, if a solid object is detected in the strip R2 and the distance

9 to the object is Z2, the distance Z1 of the strip R1 is compared

10 with the distance Z2 of the strip R2.

11 After that, the program goes to S116 where it is judged

12 whether or not the difference between the distances Z1 and Z2

13 is smaller than a threshold value and if the difference is smaller

14 than the threshold value and is close to each other, it is judged

15 at S117 that the solid object detected in the strip R2 belongs

16 to the same group G1 to label as such and then the program goes

17 to S119. At this moment, the distance to the object is established

18 to be a mean value of Z1 and Z2.

19 On the other hand, in case where the difference of the

20 distances Z1 and Z2 exceeds the threshold value, the program goes

21 from S116 to S118 in which, judging that the solid object detected

22 in the strip R2 does not belongs to the group G1, the solid object

23 is labeled as belonging to a new group G2 having a distance Z2

24 and then goes to S119.

25 At S119, it is investigated whether or not the process

26 has reached a final strip and if not, after the distance of the

27 next strip is read at S120, the program returns to S115 and further

28 the right adjacent strip is investigated. If the process has

1 reached the final strip, the program goes from S119 to S121.

2   The following case should be noted. Assuming the

3 situation where a vehicle parks beside a guardrail, there is a

4 possibility that the distance data of the guardrail are deemed

5 to belong to the same group as the distance data of the parked

6 vehicle. In order to avoid this, the arrangement direction of

7 the distance data is checked on the X-Z plane through the processes

8 at S121 to S131 to divide the group of the arrangement direction

9 into a portion in parallel with Z-axis and a portion in parallel

10 with X-axis.

11   That is, at S121 the data of the first group are read

12 and at S122 the arrangement direction of the data of the respective

13 strips is calculated. Further, at S123 these strips are labeled

14 as "object" or "side wall", respectively. Specifically, first

15 two points on the X-Z plane are picked up from the data of the

16 first group. One point (X1, Z1) is a middle point of a strip K1

17 at the left end of the first group and the other point (Xp, Zp)

18 is a middle point of a strip far away from the left end strip

19 K1 by an interval of N strips in the right hand direction. Then,

20 a line connecting these two points is drawn on the X-Z plane and

21 a gradient A1 of the line is calculated. When the gradient A1

22 is compared with a prescribed value, for example 45 degrees, if

23 the gradient A1 is larger than the value, the strip K1 is labeled

24 as "side wall" and if the gradient A1 is smaller than the value,

25 the strip K1 is labeled as "object".

26   The interval N between strips is preferably N = 2 to

27 4. The reason is that N = 1, namely, an adjacent strip may produce

28 fluctuations in the arrangement direction of the data due to the

15

1 ~~dispersion of detected distance and as a result it becomes~~

2 difficult to make discrimination between "side wall" and "object".

3 Therefore, it is suitable to use not an adjacent strip, but a

4 strip a little distant. Hereinafter, the labeling of "side wall"

5 or "object" is performed successively from the left end strip

6 up to the strip apart by N strips on the left side of the right

7 end strip.

8 ~~When the labeling is accomplished for each strip of~~

9 the group, the program goes from S123 to S124 where the label

10 of the left end strip is read and at the next step S125, the label

11 of the right adjacent strip is read. Then, it is investigated

12 whether or not the label of the left end strip is different from

13 that of the right adjacent strip. As a result, if the label of

14 the left end strip is the same as that of the right adjacent strip,

15 the program skips to S128 and if different, the program steps

16 to S127 where the strip labeled "side wall" and the strip labeled

17 "object" are divided into different groups respectively. The

18 division of the group is performed at the position apart by N/2

19 strip on the right side of the position where the label changes

20 ~~from "side wall" to "object" and vise versa.~~

21 In this case, to avoid the situation where the label

22 itself is erroneously labeled due to the dispersion of distance

23 data, the division is performed only when more than three same

24 labels are successive.

25 At S128, it is checked whether or not the process comes

26 to the final strip and if not, after reading the label of the

27 next strip at S129, the program returns to S125 and hereinafter

28 similar processes are repeated. When the process comes to the

1 final strip▉▉ program goes from S128 ▉ S130 where it is

2 investigated whether or not the process reaches the final group.

3 When the process does not yet reach the final group, the data

4 of the next group are read and hereinafter the same processes

5 are carried out repeatedly. When the process reaches the final

6 group, the division of the groups is completed and the program

7 goes from S130 to S132.

8 ~~The following steps S132 to S137 are of processes in~~

9 which further classifications of "side wall" or "object" are

10 carried out to raise the accuracy of the classification performed

11 at S127. After the data of the first group are read at S132, at

12 S133 approximate straight lines are obtained from the positions

13 (X_i, Z_i) within the group according to the Hough transformation

14 or the linear square method to calculate a gradient overall the

15 ~~group.~~

16 ~~Then, the program goes to S134 where the group is~~

17 reorganized such that the group having a gradient inclined toward

18 X-axis is classified into the "object" group and the group having

19 a gradient inclined toward Z-axis is classified into the "side

20 wall" group. Further, at S135, miscellaneous parameters of the

21 group are calculated. With respect to the group classified

22 "object", these parameters include an average distance which is

23 calculated from the distance data within the group, X-coordinates

24 at the left and right ends of the group and the like and with

25 respect to the group classified "side wall", those parameters

26 include an arrangement direction of the data (gradient with

27 respect to Z-axis), Z, X coordinates of the front and rear ends

28 ~~of the group and the like. In this embodiment, in order to raise~~

17

1 the accuracy of classification, the group is reclassified

2 according to the calculated gradient of the overall group, however

3 this reclassification may be omitted.

4 Further, the program goes from S135 to S136 where it

5 is judged whether or not the process has reached the final group.

6 If it is not the final group, the program goes back to S137 in

7 which the data of the next group are read and returns to S133

8 to repeat the same processes. When the process has reached the

9 final group, the program leaves the routine.

10 Fig. 12 shows a result of the detection of the side

11 wall. When the data of the groups are illustrated on the X-Z plane,

12 as shown in Fig. 13, they are recognized as "side wall" groups.

13 In this case, portions along a curved road are not recognized.

14 The program shown in Fig. 6 is for recognizing the wall surface

15 along the curved road using the data of the "side wall" group

16 obtained by the program described before.

17 First, at S201, groups estimated to be a wall surface

18 are selected from the groups classified "side wall" and at the

19 steps after S202, a wall surface is searched based on the data

20 of the "side wall" groups using the following wall surface model.

21 The wall surface model is shown in Fig. 14, in which

22 the wall surfaces are expressed as border lines connecting between

23 nodes provided at a specified interval within a given range. For

24 example, the border line is constituted by 41 nodes arranged at

25 an interval of 2 meters within an range from 10 to 90 meters ahead

26 of the self vehicle. Respective nodes have successive reference

27 numbers starting from the self vehicle side. The Z-coordinates

28 of the respective nodes are fixed with respect to the vehicle

18

1 position and X-coordinates thereof are determined according

2 to the procedure which will be described hereinafter.

3 At S202, a node N_s corresponding to an end point on the

4 vehicle side of the selected side wall group is established based

5 on the Z-coordinate of the end point and the X-coordinate of the

6 node N_s is established being adjusted to the X-coordinate of the

7 end point. Next, the program goes to S203 where the next node

8 N_{s+1} is established in the direction of the gradient of the side

9 wall group. Next, when the node N_{s+i} ($i \geq 2$) is determined, its

10 direction is established along a direction of the second previous

11 node.

12 Then, the program goes to S204 where, as shown in Fig.

13 15, the position of the wall surface is searched by a so-called

14 "pattern matching" within a specified searching range to extract

15 a solid object P_i for every strip within the searching range. For

16 example, the searching range in the X-axis direction has ± 3 to

17 5 meters in the X-axis direction and ± 1 meter in the Y-axis

18 direction with its center placed at a coordinate (X_{ns+i}, Z_{ns+i}) of

19 the node N_{s+i} established at S203.

20 The matching of the wall surface pattern is performed

21 to the solid object P_i within the searching range. Fig. 16 shows

22 an example of the wall surface pattern (weight coefficient

23 pattern) used for the pattern matching. The wall surface pattern

24 shown in Fig. 16 is a pattern for the wall surface on the left

25 side and a symmetric pattern to this pattern is used for the wall

26 surface on the right side. The lateral axis of this wall surface

27 pattern coincides with the distance in the X-axis direction and

28 the longitudinal axis indicates a weight coefficient. A maximum

1 point of a degree of coincidence is searched while the central

2 point of the wall surface pattern is shifted towards the X-axis.

3 Specifically, as shown in Fig. 17, a weight W_i is obtained with

4 respect to the deviation of the solid object P_i in the X-axis

5 direction from the central point of the wall surface pattern to

6 calculate the sum of the weight W_i as a degree of coincidence F.

7 Further, when the degree of coincidence F becomes maximum, the

8 position of the central point of the wall surface pattern is

9 recognized as a wall surface. When the maximum value of the degree

10 of coincidence F is smaller than a threshold value, it is judged

11 that there is no wall surface.

12   When the process of the step S204 finishes, the program

13 goes to S205 at which a X-coordinate X_{pw} of the central point of

14 the wall surface pattern at the maximum point of the degree of

15 coincidence F, is established as a X-coordinate of the wall

16 surface pattern corresponding to the node N_{s+i}.

17   Then, the program goes to S206 where it is checked

18 whether or not the node is the last one of the side wall group

19 selected and if it is not the last node, the program goes back

20 to S203 and the same processes are repeated. When the process

21 reaches the last node, the program steps to S207 where the node

22 having the smallest reference number (the node nearest to the

23 self vehicle) and the node having the largest reference number

24 (the node furthermost from the self vehicle), are searched

25 respectively and leaves the routine after denoting them as a start

26 point N_s and an end point N_e, respectively.

27   After this program is carried out on the side wall

28 groups on the left side, it is carried out on the side wall groups

1   on the right side. In the example shown in Fig. 14, the wall surface

2   from the 9th node to the 26th node is detected on the right side

3   of the self vehicle and the 9th node is denoted as the start point

4   N_s and the 26th node is denoted as the end point N_e. These nodes

5   are used for later processes as effective nodes.

6   Thus processed position of the wall surface is further

7   corrected by a program shown in Fig. 7 and Fig. 8 using new data

8   obtained from programs shown in Fig. 3 through Fig. 5.

9   The programs shown in Fig. 7 and Fig. 8 is a program

10   for correcting the wall surface. At S301, it is investigated

11   whether or not the start point N_s of the effective nodes is larger

12   than the first node N_1 of the wall surface model. When $N_s = N_1$,

13   the wall surface has been already detected up to the first node

14   N_1, the program skips to S306. When $N_s > N_1$, the program goes to

15   S302 where the previous node N_{s-i} (i = 1, 2, 3 etc.) is established.

16   Then, at S303 the wall surface pattern is searched and at S304

17   the X-coordinate of the wall surface is determined based on the

18   result of searching.

19   Next, the program goes from S304 to S305 where it is

20   investigated whether or not the process has reached the first

21   node. If not yet reached the first node N_1, the steps S302 to S304

22   are repeated to continue the searching of the wall surface

23   position up to the node N_1. When the processes up to the first

24   node N_1 are finished, the program goes to S306 where it is checked

25   whether or not the end point N_e of the effective nodes is smaller

26   than the last node N_{se} of the wall surface model (for example,

27   node N_{41} in case of the wall surface model constituted of 41 nodes).

28   As a result of this, when $N_e = N_{se}$, that is, the wall

1   surface has been already detected up to the last node, the program

2   skips from S306 to S311. When $N_e < N_{se}$, the program goes from S306

3   to S307 where the node N_{e+1} after the end point N_e is successively

4   established and further at S308 the pattern matching of the wall

5   surface is performed. According to the result of the pattern

6   matching, at S309 the X-coordinate of the wall surface is

7   determined and then at S310 it is checked whether or not the process

8   has reached the last node N_{se}. The matching of the wall surface

9   position is continued until the last node N_{se} and when the processes

10   up to the last N_{se} is finished, the program goes to S311.

11   These processes of establishing the nodes, the matching

12   of the wall surface pattern and the determination of the X-

13   coordinate at the steps S302 to S304 and the steps S307 to S309,

14   are the same as the processes at the steps S203, 204 and S205

15   in the aforementioned program of the wall surface detecting

16   process.

17   The processes after S311 are for correcting the

18   position (X-coordinate) of respective nodes from the first node

19   N_1 to the last node N_{se}. First, at S311 the data of the first node

20   N_1 is set and the program goes to S312. The processes from S312

21   to S321 are repeatedly carried out by successively setting the

22   data of the next node.

23   At S312, the wall surface at the node N_i is searched

24   and at S313 it is checked whether or not the wall surface is

25   detected by the pattern matching. If it is judged that the wall

26   surface is detected, the program goes from S313 to S314 where

27   it is investigated whether or not the difference between the

28   position X_{pw} of the wall surface and the position X_{ni} of the node

1   is within a prescribed amount, for example, ± 1 meter. If the

2   difference is within the value, the program goes to S315 where

3   the node is moved to the position of the wall surface $(X_{ni} \leftarrow X_{pw})$

4   and if the difference is out of the value, the program goes to

5   S316 where the node is moved toward the wall surface by a specified

6   amount, for example, ± 0.3 meters $(X_{ni} \leftarrow X_{ni} \pm 0.3$ meters).

7   On the other hand, when the wall surface is not detected

8   by the pattern matching, the program diverges from S313 to S317

9   where the number C_0 of the data X_{pi} of the solid objects located

10 on the left side of the node X_{ni} $(X_{ni} < X_{pi})$ and the number C_1 of

11 the data X_{pi} of the solid objects located on the right side of

12 the node X_{ni} $(X_{ni} > X_{pi})$, are counted respectively. Then, at S318

13 the node is moved towards the side having more data of solid objects

14 by a specified amount, for example 0.8 meters $(X_{ni} \leftarrow X_{ni} \pm 0.8$

15 meters).

16   Thus, in case where there is no wall surface pattern

17 detected near the node, the position of the node can be neared

18 in the direction where the wall surface likely exists even when

19 the node is largely apart from the wall surface.

20   When the position of the node is moved through either

21 step of S315, S316 and S318, the program goes to S319 where a

22 position X_c of a mid-point of a straight line connecting a node

23 N_{i+1} (adjacent node on far side) and a node N_{i-1} (adjacent node on

24 near side) is obtained and then goes to S320 where, as shown in

25 Fig. 18, the node N_i is moved toward the mid-point X_c just like

26 in a manner that the mid-point X_c attracts the node N_i by a spring

27 force. The amount of the movement should be retained as much as

28 1/2 to 1/5 of the length between the node N_i and the mid-point

1   X_c.

2   That is, the wall surface detected by the pattern

3   matching generally contains irregularity due to the effect of

4   the dispersion of data but a real guardrail or real side wall,

5   in most case, is smoothly curved along a road. The process at

6   S320 is a means for obtaining a smooth curve by applying a spring

7   operation as described above. As a conventional method of

8   smoothing the configuration composed of nodes, a least square

9   method is well known, however the aforegoing method using a

10   spring operation is more advantageous in calculation speeds than

11   such a conventional method.

12   After that, the program goes to S321 where it is

13   investigated whether or not the process has reached the last node

14   N_{se} and if it has not reached the last node point, the program

15   returns to S321 after setting the data of the next node at S322

16   and the same processes are repeated. When the process at the last

17   node N_{se} is finished, the program goes from S321 to S323 where

18   it is checked whether or not the amount of the movement comes

19   within a threshold value (for example, ± 0.1 meters) for all of

20   the points.

21   Further, if a node exceeding the threshold value is

22   found, the program goes back to S311 and thereafter the correcting

23   processes are repeated for all nodes from the first to the last.

24   When the amount of the movement for all node points comes within

25   the threshold value, the start point N_s and the end point N_e within

26   the detecting range of the nodes are obtained and the program

27   leaves the routine. Through thus constituted program, erroneously

28   detected data and others are corrected during repeated processing

24

1 and as a result the configuration of the wall similar to the actual

2 wall surface is obtained. After the program is finished to be

3 carried out with respect to the side wall groups on the left side,

4 the program is carried out with respect to those on the right

5 side.

6   Fig. 19 shows a result of the detection of the wall

7 surface located from near to far along a curved road on the basis

8 of the original image shown in Fig. 9 and the corrected wall surface

9 model expressed on a X-Z plane is shown in Fig. 20. Comparing

10 this wall surface model with the one detected in the form of

11 straight lines as shown in Fig. 13, it is understood that the

12 wall surface can be recognized up to far.

13   This wall surface model can be applied not only to a

14 guardrail but also to a line of trees, walls of houses, an array

15 of parked cars and other solid objects lined along a road and

16 these objects can be detected as a series of wall surfaces.

17 Therefore, it is possible to recognize the configuration of a

18 road even in case of a road whose lane markers can not be recognized,

19 for example a snow-covered road.

20   While the presently preferred embodiment of the present

21 invention has been shown and described, it is to be understood

22 that this disclosure is for the purpose of illustration and that

23 various changes and modifications may be made without departing

24 from the scope of the invention as set forth in the appended claim.